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**GEOPHYSICAL PARAMETERS FROM THE ANALYSIS
OF LASER RANGING TO STARLETTE**

NASA GRANT NAG5-757

**Annual Research Technical Report
for the period
March 15, 1986 - March 14, 1987**

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NASA Grant NAG5-757

SUMMARY

The University of Texas Center for Space Research (UT/CSR) research efforts under NASA Grant NAG5-757 during the time period from March 15, 1986, through March 14, 1987, have concentrated on the following areas:

- Refining force, earth orientation and measurement models for precise determination of Starlette orbits,
- Preparing, cataloging, pre-processing, and processing Starlette laser ranging data (both quick-look and full-rate data) from 1976 to the present,
- Determining earth rotation parameters (ERP) using satellite laser ranging (SLR) data to Starlette,
- Precise orbit determination for a long and continuous three-year orbit spanning from 1983 to 1985 using quick-look data,
- Mapping the tidal response of the earth using Starlette data,
- Determining observed seasonal variations from Starlette node residuals and comparing with other independently derived parameters.

Copies of abstracts for some of the publications and conference presentations are included in the appendices.

STARLETTE MODEL REFINEMENT

Starlette SLR data were used, along with several other satellite data sets, for the solution of a preliminary gravity field model for TOPEX, PTGF1. PTGF1 is a significant improvement over the

GSFC Starlette-tailored field, PGS-1331, in terms of orbit determination on Starlette. PTGF1 is fitting 5-day Starlette orbits with a range residual under 25 cm rms, and a 92-day long arc for Starlette using PTGF1 was computed to fit SLR data at range residuals of 1 m rms, thereby enabling identification of signals produced by geophysical phenomena.

A further improvement in the earth's gravity model was accomplished using data collected by 12 satellites to solve for another preliminary gravity model for TOPEX, designated PTGF2. PTGF2 shows slight improvement over PTGF1 in terms of Starlette orbit fits.

A nominal model for absolute plate motion has been adopted. The Minster and Jordan AM1-2 model, in which the relative motions are relative to a mantle-fixed frame through the use of presumably stationary hot spots, has been implemented to comprise part of the Conventional Terrestrial System (CTS). An improved and consistent polar motion model and the corresponding laser tracking station coordinates (CSR 8604) have been derived incorporating the AM1-2 plate motion model.

The atmospheric drag model used for Starlette orbit computation is the French Density Temperature Model (DTM). Preliminary evaluation of the DTM model versus the Jacchia models (1971, 1977) indicates that the DTM performs more reasonably over a variety of altitudes and meteorological phenomena.

STARLETTE DATA AND ORBIT ANALYSIS

Quick-look Starlette data from 1983 to the present have been processed on a regular basis. Full-rate data from 1976 through 1977 have been processed and compressed into normal points. The quick-look data during and after the MERIT Campaign period were collected by more than 20 laser stations worldwide and generally have an average of about 6–10 observation passes per day. Full-rate data from 1980–83 have been preprocessed. Efforts are underway to process and edit the data and to compress into normal points.

Long, continuous and dynamically consistent Starlette ephemerides have been precisely determined. These orbits include a one-year arc during 1976–77 and a three-year long arc during 1983–85 using PTGF1. Quick-look normal points were used in the computation of the 1983–85 three-year arc. The range residual rms for the 1976–77 orbit is ~1 m and the 1983–85 orbit is ~4 m. The three-year arc is both computationally expensive and difficult to determine precisely. Efforts are underway to investigate the feasibility of extending the three-year orbit for the examination of interesting geophysical parameters.

DETERMINATION OF EARTH ROTATION PARAMETERS

The solution for the ERP has been derived from the analysis of SLR data to Starlette during the MERIT Campaign from August 30, 1983, to December 2, 1984. This activity has been pursued as an evaluation of the quality of the current force models. A covariance analysis indicates that the accuracy of the Starlette ERP solution is limited primarily by errors in the earth's gravity field model. The previous Starlette ERP solution computed using the PGS-1331 gravity field has a weighted rms difference compared with the Lageos ERP solution of about 15 mas for the polar motion coordinates, x and y . The improved ERP solution using the PTGF1 gravity field has a weighted rms difference compared with the Lageos solution of about 5 mas for x and y , thereby providing a measure of the quality of this new gravity field.

MAPPING OF TIDAL RESPONSE

Starlette orbits in 1976 and 1983 were analyzed for the mapping of the tidal response of the earth. Long period perturbations due to ocean tide mismodeling on the Starlette orbit were analyzed. Ocean tidal constituents were determined using precisely determined Starlette long arcs. The uncertainties for most of the estimated tidal coefficients are less than 0.1 cm. The effective k_2 values of the ocean tide parameters derived from the 1976–77 long-arc analysis differ from Schwiderski

ocean tide model by roughly 0.003 for diurnal and semidiurnal tides. Theoretical values for the lunar deceleration have been computed using the estimated semidiurnal and diurnal tides. The values obtained are in good agreement with those obtained by other investigators.

Using the 1976–77 one-year arc and the 1983–85 three-year arc, the observed nontidal seasonal variations due to the changes in the earth's even zonal harmonics have been computed. Annual and semiannual seasonal variations were determined from the four one-year Starlette node residuals. These Starlette-observed parameters were tabulated and compared with the values derived using 10-year Lageos data as well as values determined by independent investigators using air pressure and water mass redistribution data. Although the Starlette-determined seasonal amplitudes are high compared to the values determined using the meteorological data, the phases are in general agreement.

PUBLICATIONS/PRESENTATIONS

The following is a list of publications and conference presentations pertinent to research activities under NASA Grant NAG5-757:

- *Starlette Data Analysis*, C. K. Shum. Presented at the Sixth UT/GSFC TOPEX Gravity Model Development Meeting held at The University of Texas at Austin, April 8–10, 1986.
- *Earth Rotation Solution From Starlette Orbit Analysis*, B. E. Schutz, M. K. Cheng, C. K. Shum, B. D. Tapley, and R. J. Eanes. To be submitted for publication in the *Journal of Geophysical Research*, May 1987. A copy of the abstract is attached in Appendix A.
- *Long Period Perturbations in Starlette Orbit and Tide Solution*, M. K. Cheng, B. E. Schutz, C. K. Shum, B. D. Tapley, and R. J. Eanes. To be submitted for publication in *Bulletin Geodesique*, May 1987. A copy of the abstract is attached in Appendix B.
- *Starlette Geodynamics*, C. K. Shum. Presented at the 12th Crustal Dynamics Principal Investigators Meeting at the Jet Propulsion Laboratory, March 24–26, 1987.

- *Geophysical Parameters From the Analysis of Laser Ranging to Starlette*, C. K. Shum, B. E.

Schutz, M. K. Cheng, R. J. Eanes, and B. D. Tapley. EOS Trans. AGU, 68(16), April 21, 1987.

A copy of the abstract is attached in Appendix C.

APPENDIX A

EARTH ROTATION SOLUTION FROM STARLETTE ORBIT ANALYSIS

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ABSTRACT

The solution for the Earth Rotation Parameters (ERP), which include the polar motion coordinates, x and y , and the length of the day (LOD), have been obtained from the analysis of the satellite laser range (SLR) data to Starlette collected during the MERIT Campaign from 30 August 1983 to 2 December 1984. The Starlette ERP solutions have been compared with the solutions derived from SLR to Lageos, and the weighted rms about the mean of the difference between these solutions are 17 milliarcseconds (mas), 12 mas and 0.7 milliseconds (ms) for Δx , Δy and ΔLOD , respectively. A covariance analysis indicates that the accuracy of the Starlette ERP solution is limited primarily by errors in the earth's gravity field model. In particular, the first order geopotential coefficients produce a systematic perturbation in the solutions for x and y with a maximum value up to 29 mas and a dominant period of 74 days. With the improvement of the Starlette force model by simultaneous estimation of selected geopotential coefficients and ocean tide parameters, the weighted rms of the Starlette-Lageos differences has been reduced to 9 mas and 6 mas for Δx and Δy , respectively. Using an improved gravity field recently developed by the University of Texas Center for Space Research (UT/CSR), the weighted rms differences between Starlette and Lageos ERP solutions have been further reduced to 6 mas and 4 mas for Δx and Δy , respectively. These results show that a significant improvement of the ERP solution from Starlette can be achieved through further refinements in the earth's gravity field and tide model and that a precision of <5 mas in x and y coordinates of the ERP derived by Starlette is feasible.

APPENDIX B

LONG PERIOD PERTURBATION IN STARLETTE ORBIT AND TIDE SOLUTION

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ABSTRACT

Long, continuous and dynamically consistent orbits have been precisely determined using satellite laser ranging (SLR) data to Starlette for the one-year periods for 1976–77 and 1983–1984. The data have been analyzed to show significant long period perturbations in Starlette orbit due to error in the earth's gravity field and the modeling of its tidal response. The residual rms of laser range data have been reduced from 5 m to 2 m over the one-year orbit during 1976–1977 by simultaneous estimation of the second degree ocean tide constituents SA, SSA and K1 (degrees 2, 3 and 4) as well as low degree zonal harmonic coefficients (degrees 2 to 7). The approach for recovering tide response using analysis of long satellite orbital arcs was investigated. A total of 14 ocean tidal constituents (48 parameters) were estimated using long arcs \geq one year during 1976–77 and 1983–1984 with a least squares process. The uncertainties for the most of the estimated tidal coefficients are lower than 0.1 cm, the effective k_2 values for the diurnal and semidiurnal tides solution are in good agreement with the Schwiderski and Parke ocean tide model and other satellite-derived solutions. Theoretical values for the lunar deceleration have been computed using the estimated semidiurnal and diurnal tides. The values obtained are in good agreement with those obtained by other investigators. Seasonal variations caused by even and odd zonal perturbations were observed in the node, eccentricity and perigee residuals for the Starlette long arcs, indicating that Starlette's orbit is sensitive to long period seasonal changes in the earth's gravity field. The observed seasonal variations have been computed. A preliminary comparison with the seasonal variations obtained by other investigators using meteorological data shows the values are in general agreement.

APPENDIX C

**GEOPHYSICAL PARAMETERS FROM THE ANALYSIS
OF LASER RANGING TO STARLETTE**

C. K. Shum (Center for Space Research, The University of
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B. E. Schutz, M. K. Cheng, R. J. Eanes, and B. D. Tapley

The Starlette satellite, launched in 1975 by the French Centre National d'Etudes Spatiales (CNES), has provided valuable information in the areas of geodesy and geodynamics. Using a preliminary gravity model developed at the University of Texas Center for Space Research (UT/CSR), five-day Starlette orbits were computed at the level of ~ 20 cm laser range residual rms. Quick-look Starlette data have been processed at UT/CSR on a regular basis since 1983. From dynamically consistent long arcs of one to three years, geodetic and geodynamic parameters of interest have been deduced from laser ranging to Starlette. In particular, earth rotation parameters have been determined, and other geophysical phenomena such as the seasonal variations of the long period tidal constituents have been examined.

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1. 1987 Spring Meeting
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